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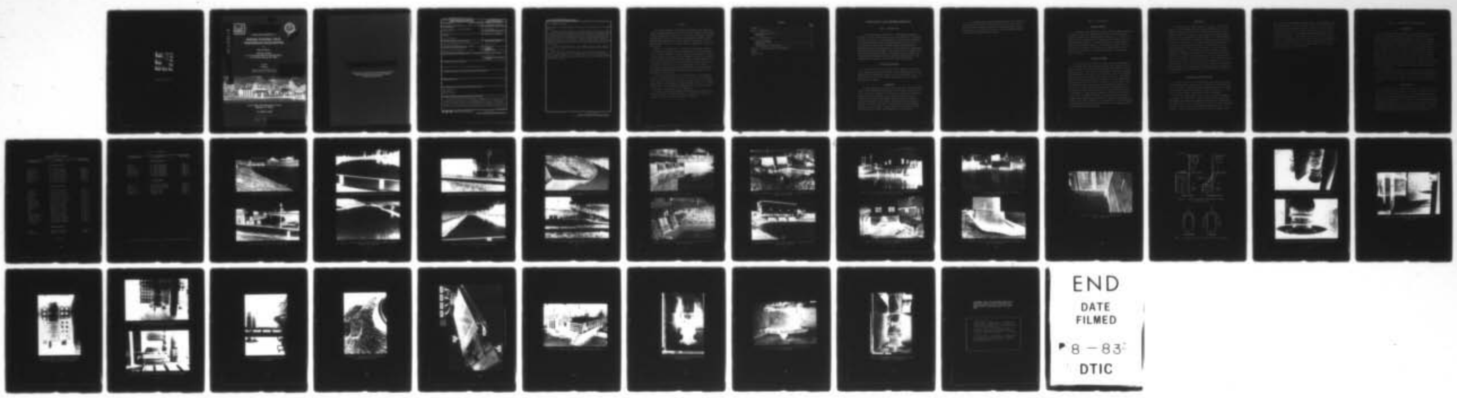

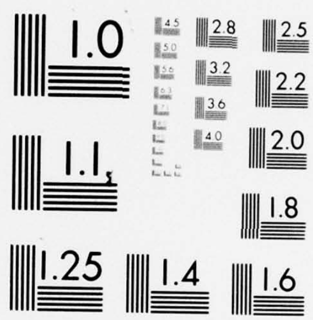

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PUMPING STATIONS - FIELD PERFORMANCE INVESTIGATION

by

Bobby P. Fletcher

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July 1979

Final Report

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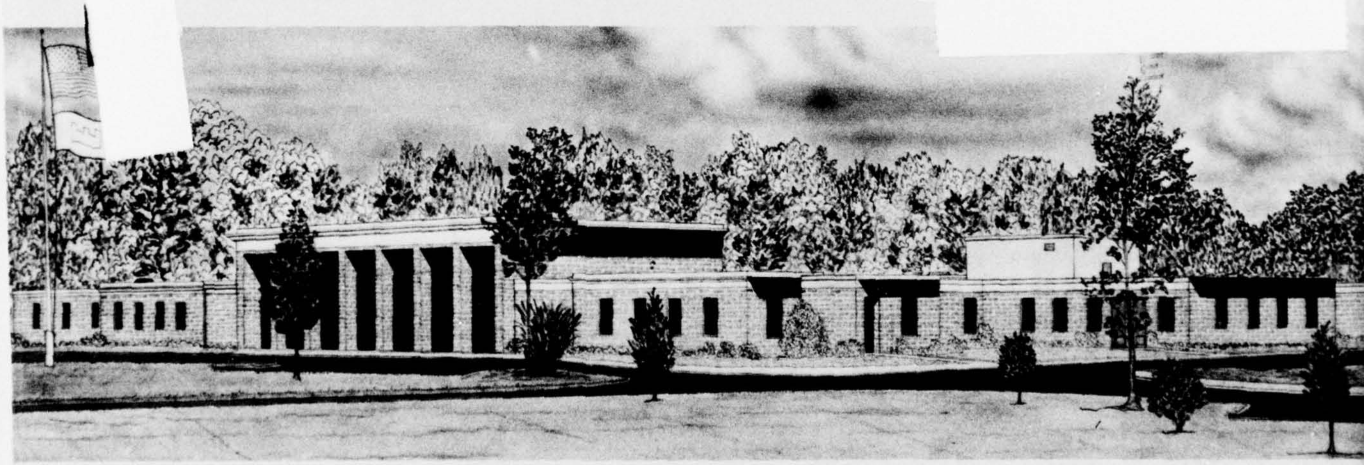

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Very little documentation or guidance is available for the design of channel approaches and sumps, which are important components in the hydraulic performance of pumping stations. To develop guidance for design of approaches and pumping stations, limited field performance investigations were conducted. Evaluation of field performance was based upon the observation of 42 facilities in five Corps of Engineers Districts and discussions with representatives of

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20. ABSTRACT (Continued).

those districts regarding hydraulic performance and problem areas at the pumping stations.

Observations and discussions of the various pumping stations, which range in age from 4 to 44 years, indicated that the best hydraulic performance occurred at stations with the most symmetrical geometry and uniformly distributed flow to the pump intakes. Satisfactory flow conditions were usually provided by a relatively long and straight approach channel, a streamlined transition from the approach channel to the sump, and a symmetrical sump design. Eddies and adverse circulation of flow, generated by curved approach channels and/or abrupt transitions from the approach channel to the sump, tended to induce vortexes in the sump.

Postconstruction modifications such as umbrellas, vanes, grids, floats, and fillets were reported to be effective in reducing adverse flow conditions in sumps. Tests have been initiated

During April 1978, WES initiated tests in a general research facility capable of simulating a variety of pumping stations. The facility will be used to conduct systematic tests and data analyses in order to develop guidance for design of approach channels and sumps for all but the more complicated and unique pumping stations.

PREFACE

The field performance investigations described in this report were conducted during May and June 1975 as a work unit, "Pump Station Inflow-Discharge Hydraulics," under the U. S. Army Corps of Engineers Locks and Dams Research Program. The effort was accomplished by the U. S. Army Engineer Waterways Experiment Station (WES) with assistance from U. S. Army Engineer Districts, St. Louis, Louisville, Memphis, St. Paul, and Rock Island.

Messrs. J. P. Bohan and B. P. Fletcher of the Hydraulics Laboratory (HL), WES, conducted the field investigations with the assistance of the following personnel: Messrs. Jim Luther and Doug Hoy, St. Louis District; Messrs. Jim Hamilton and Bill Chambers, Louisville District; Messrs. Hugh Wardlaw and Claudy Thomas, Memphis District; Messrs. Pete Fisher and Gary Erickson, St. Paul District; and Messrs. Sam Doak and Ed Grummer, Rock Island District. Acknowledgment is also made to Mr. John R. Robertson, OCE, the Technical Monitor of the ongoing Electrical and Mechanical Research Program, who provided guidance in the preparation of this report.

This report was prepared by Mr. Fletcher under the direction of Messrs. H. B. Simmons, Chief, HL, and J. L. Grace, Jr., Chief, Hydraulic Structures Division, and under the supervision of Mr. J. P. Bohan, former Chief of the Spillways and Channels Branch, and Mr. N. R. Oswalt, present Chief of the Spillways and Channels Branch. It has been reviewed by Mr. Grace and Mr. John R. Robertson.

Directors of WES during conduct of the study and the preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

PUMPING STATIONS - FIELD PERFORMANCE INVESTIGATION

PART I: INTRODUCTION

1. During fiscal year 1975, the U. S. Army Engineer Waterways Experiment Station (WES) investigated the field performance of 42 pumping station facilities. Field performance was determined by observation of facilities and discussions with representatives from each of the five district offices visited. Several diverse problems were indicated, and the field investigations of some stations were supplemented by movies and model study reports. The objectives of the subject investigation were to provide guidance for laboratory research efforts by familiarizing WES personnel with the operation, various problems, and postconstruction measures associated with field installations.

Installations Observed

2. The facilities observed ranged from 44 years old to those recently completed and usually consisted of diesel powered pumps in rural areas and electrically powered pumps in urban or industrial areas. The pumping stations visited by personnel from the WES and local offices are presented in Table 1.

Background

3. Pump manufacturers and other researchers have done considerable work in positioning pumps with respect to the sidewalls, backwall, and floor of the sump to minimize the tendency for adverse flow conditions. However, except on specific projects, little work has been done to investigate the effects that upstream and sump entrance conditions will have on approach flow to pumps. Experience has shown that more guidance is needed in this area to avoid operational and maintenance problems and to avoid expensive postconstruction modifications which would be needed to improve adverse hydraulic flow conditions.

4. It was anticipated that the knowledge gained from the field investigations would provide insight for the design of a test facility and the conduct of generalized tests to develop quantitative design guidance for all but the larger and more complicated pumping stations that warrant a site-specific model study.

PART II: OBSERVATIONS

Approach Channels

5. A variety of the straight and curved approach channels observed are shown in Figures 1-8. Observation of flows in various geometric shapes and alignments of approach channels (Figures 1, 4, 5, and 6) indicated that flow conditions at the pumps were more favorable with long, straight approach channels. At some structures the sump was skewed relative to the approach channel. In most cases it appeared that more consideration was given to the design of the approach channel to the gravity flow structure than to the approach channel to the pumping station (Figure 8).

Entrances to Sumps

6. Various types of entrances to sumps were observed (Figures 9-17). It appeared that the transition from the approach channel to the sump was a major factor affecting the hydraulic performance of several pumping stations. These stations had inadequate transitions consisting of abrupt abutment walls that tied into the side slopes of the approach channel at a 90-deg (1.6-rad) angle (Figures 10 and 18). Flow passing abrupt changes in geometry tended to separate from the sidewalls and an eddy would usually form as shown in Figure 18a. Stations with 45-deg (0.8-rad) wing walls also experienced flow separations (Figure 17), although not as severe as those observed with the 90-deg wing walls. The eddies and uneven flow distribution to the pumps can be reduced or eliminated by streamlining the transition from the approach channel to the sump. A streamlined transition usually consists of vertical quadrant walls between the side slopes of the approach channel and the entrance of the sump (Figure 18b). Flow separation at the upstream end of the pump divider walls was improved by the use of streamlined rather than square pier noses (Figure 19).

Sump Design

7. Numerous types of sump designs were observed. Inflow to the sumps was usually provided by ponded areas, open channels, or closed conduits and entered the sumps from various directions and elevations relative to the floor of the sump. Some sumps had no divider walls to separate flow as it approached the pump intakes. Some sumps included divider walls (Figure 20) to separate the pumps and reduce the possibility of interaction of flow. The lengths of the walls ranged from 1 to 10 diameters of the pump discharge pipe. The divider walls in some stations included an opening to permit passage of personnel between adjacent pump bays. It is possible that flow through these openings could have a significantly adverse effect on flow conditions and pump performance. In some cases the divider walls provided support for the motors and trashracks. Distances from the bell of the pump to the back sump wall ranged from 1 in. (25 mm) to about 5 diameters of the pump discharge pipe. After observing several installations, it was apparent that the design of most sumps varied considerably, depending primarily on the location of the pumping station, and there was no consistency in the designs.

Postconstruction Modifications

8. About 50 percent of the sumps observed had hydraulic problems or had postconstruction modifications to improve the hydraulic performance of the sump. Usually the adverse performance consisted of vibration, cavitation, noise, and vortexes and was considered to be a result of poor approach channel, sump entrance, and/or sump design.

9. Certain devices were reported to have improved the hydraulic performance of several sumps. At some stations, it was reported that the hydraulic performance was improved by the addition of umbrellas to the pumps (Figures 21 and 22), which were considered to have streamlined the direction and reduced the magnitude of intake velocities. Vanes (Figures 23 and 24) have been located below the pump intake to guide

flow entering the pump intake; however, there is no documentation as to their effectiveness. At several pumping stations a vertical grid was installed on the rear sump wall (Figures 23 and 24) to reduce adverse circulation behind the pumps. Wooden grids (Figures 25 and 26) were installed horizontally to attentuate surface turbulence and reduce the tendency for vortexes. Surface floats (Figure 27) have been used to prevent air entrainment in vortexes; however, they do not prevent circulation of the flow and the associated area of low pressure. Fillets have been installed in corners and sidewall offsets in an attempt to reduce turbulence and flow separation.

PART III: CONCLUSIONS AND FUTURE RESEARCH

Conclusions

10. From observations of pumping stations with various approaches, entrances, and sumps, and discussions with operating personnel, it appeared that the best hydraulic performance occurred at the pumping stations with the most symmetrical geometry and uniformly distributed flow to the pump intakes. Symmetrical flow was best provided by a relatively long and straight approach channel, a streamlined transition from the approach channel to the sump, and a symmetrical sump design. Curved approach channels and/or abrupt transitions from the approach channel to the sump tended to generate eddies and induce an adverse circulation of flow, resulting in vortexes after entering the sump. Inadequate sump design, characterized by adverse circulation and vortexes in the sump, usually included slope breaks in the sidewalls and/or floor, improper distances from the pump to the rear wall, and/or inadequate divider wall lengths.

11. Postconstruction modifications such as umbrellas, vanes, grids, floats, and fillets were reported to be effective in reducing the adverse flow conditions in the sumps; however, there is no documentation or guidance as to how, when, and where those types of modification may be used.

Future Research

12. During April 1978, WES initiated tests in a general research facility (Figures 28 and 29) capable of simulating a variety of pumping stations. The facility will be used to conduct systematic tests and data analyses for developing design guidance for all but the more complicated and unique stations. This research will address adverse hydraulic conditions (Figures 30-32) that can occur due to improper design of the approach channel and/or sump. The results of ongoing site-specific model studies of proposed and existing pumping stations will be used to supplement the results of the generalized research effort also.

Table 1

Pumping Stations Observed

Installation	Location	Date Visited
	St. Louis District	
Mill Creek	St. Louis, Missouri	22 May 75
Poplar Street	St. Louis, Missouri	22 May 75
Lesperance	St. Louis, Missouri	22 May 75
Cohonia	St. Louis, Missouri	22 May 75
East St. Louis	St. Louis, Missouri	22 May 75
Palmer Creek	St. Louis, Missouri	22 May 75
South	St. Louis, Missouri	22 May 75
Canal No. 1	St. Louis, Missouri	22 May 75
	Louisville District	
Willow Run	Covington, Kentucky	19 May 75
24 Street	Covington, Kentucky	19 May 75
Falling Run	New Albany, Kentucky	19 May 75
Slate Run	New Albany, Kentucky	19 May 75
Woerner	Jeffersonville, Kentucky	19 May 75
Mill Creek	Jeffersonville, Kentucky	19 May 75
Turtle Creek	West Central Indiana	20 May 75
Rogers Ditch	West Central Indiana	20 May 75
Highland Street	Vincennes, Indiana	20 May 75
Second Street	Vincennes, Indiana	20 May 75
Sycamore	Evansville, Indiana	20 May 75
H-4	Evansville, Indiana	20 May 75
K-4	Evansville, Indiana	20 May 75
Fourth Street	Cannecton, Indiana	21 May 75
Castleberry Creek	Cannecton, Indiana	21 May 75
Shawnee Park	Louisville, Kentucky	21 May 75
Western Parkway	Louisville, Kentucky	21 May 75
10th Street	Louisville, Kentucky	21 May 75
Bear Grass	Louisville, Kentucky	21 May 75
	Memphis District	
Ensley	Memphis, Tennessee	30 Apr 75
Graham Burke	Memphis, Tennessee	1 May 75

(Continued)

Table 1 (Concluded)

Installation	Location	Date Visited
	St. Paul District	
Wheeler	St. Paul, Minnesota	5 May 75
Sherman	St. Paul, Minnesota	5 May 75
Honey Mead	St. Paul, Minnesota	5 May 75
Stockyard North	St. Paul, Minnesota	6 May 75
Grand Avenue	St. Paul, Minnesota	6 May 75
Moses Street	St. Paul, Minnesota	6 May 75
Chester Street	St. Paul, Minnesota	6 May 75
	Rock Island	
Muscatine	Rock Island, Illinois	8 May 75
Drury	Rock Island, Illinois	8 May 75
Bay Island	Rock Island, Illinois	8 May 75
Maus Barn	Dubuque, Iowa	9 May 75
Harbor Closure	Dubuque, Iowa	9 May 75
Hawthorne	Dubuque, Iowa	9 May 75

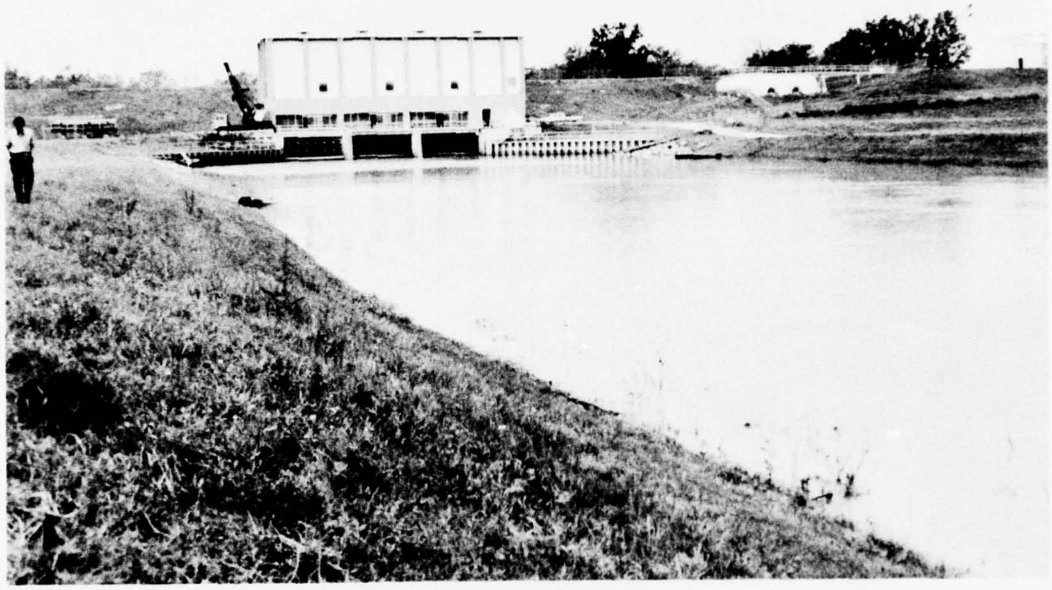

Figure 1. Straight approach channel

Figure 2. Approach channel with reverse curve

Figure 3. Curved approach channel viewed from pumping station

Figure 4. Straight approach channel viewed from pumping station (trashrack in background)

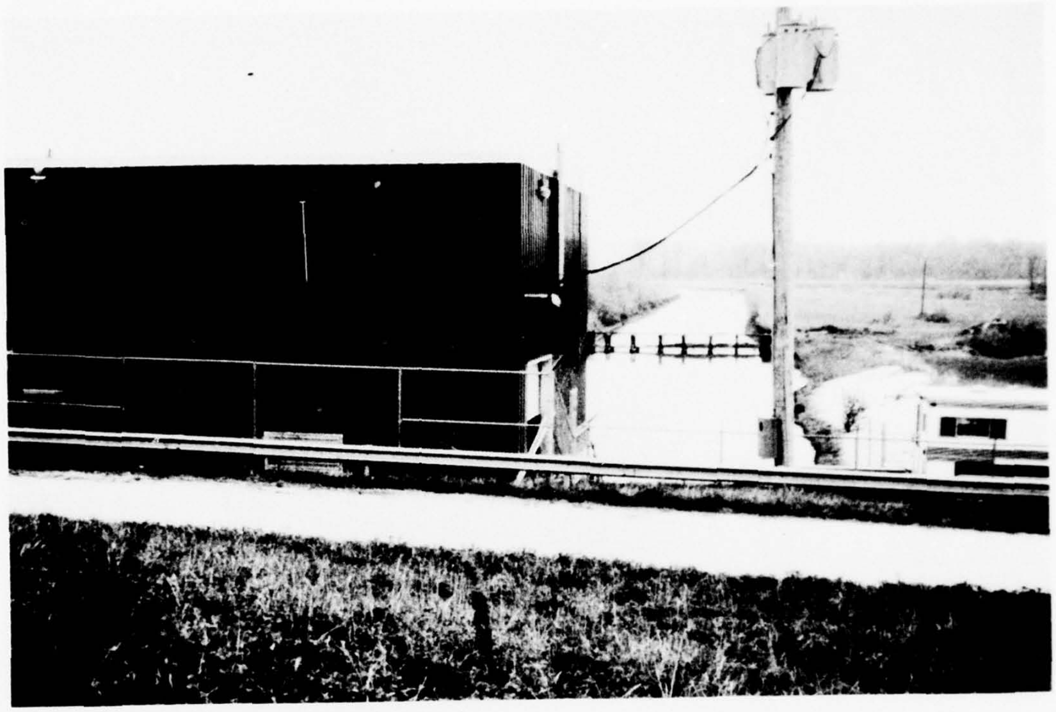

Figure 5. Straight approach channel (trashrack in background)

Figure 6. Long reach of straight approach channel

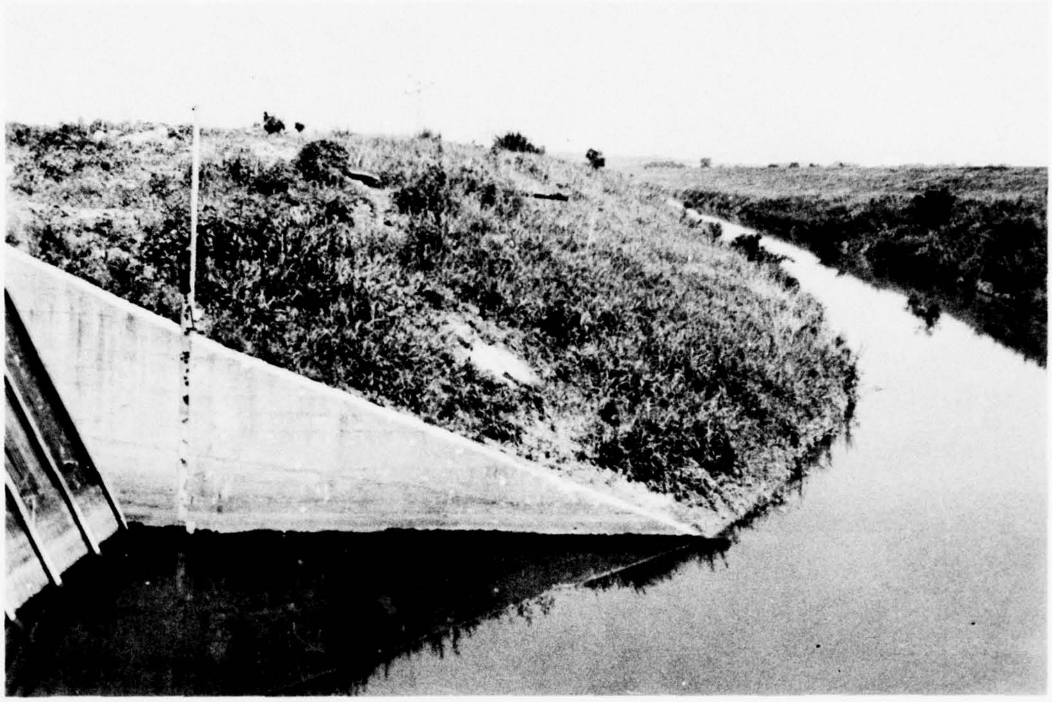

Figure 7. Approach channel and pumping station oriented 90 deg to main channel

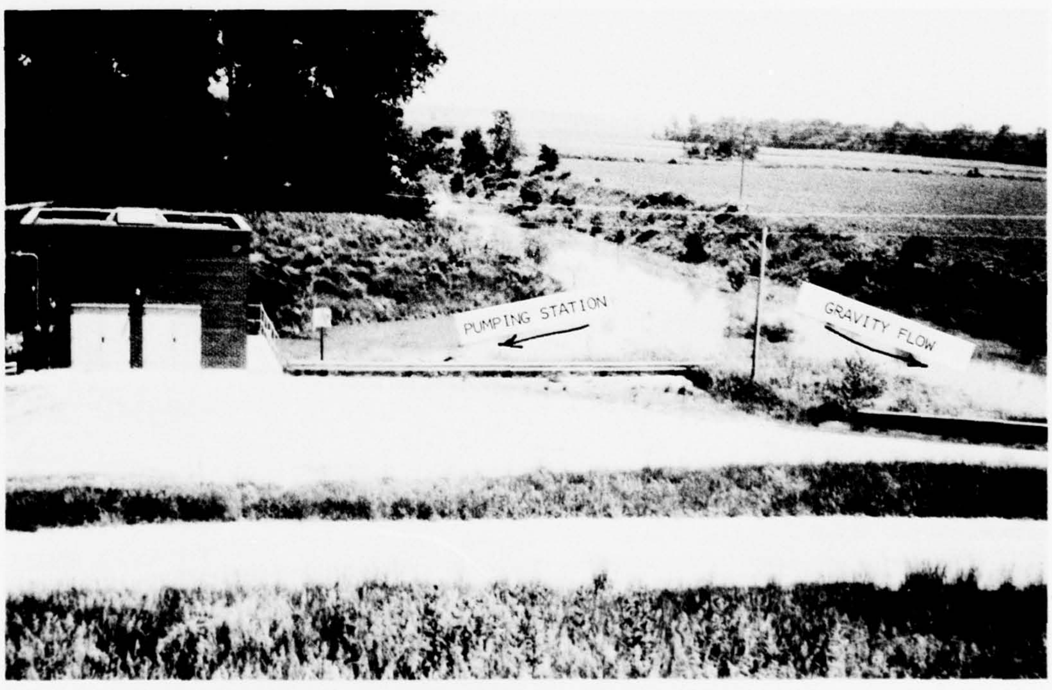

Figure 8. Pumping station and approach channel offset from gravity flow section

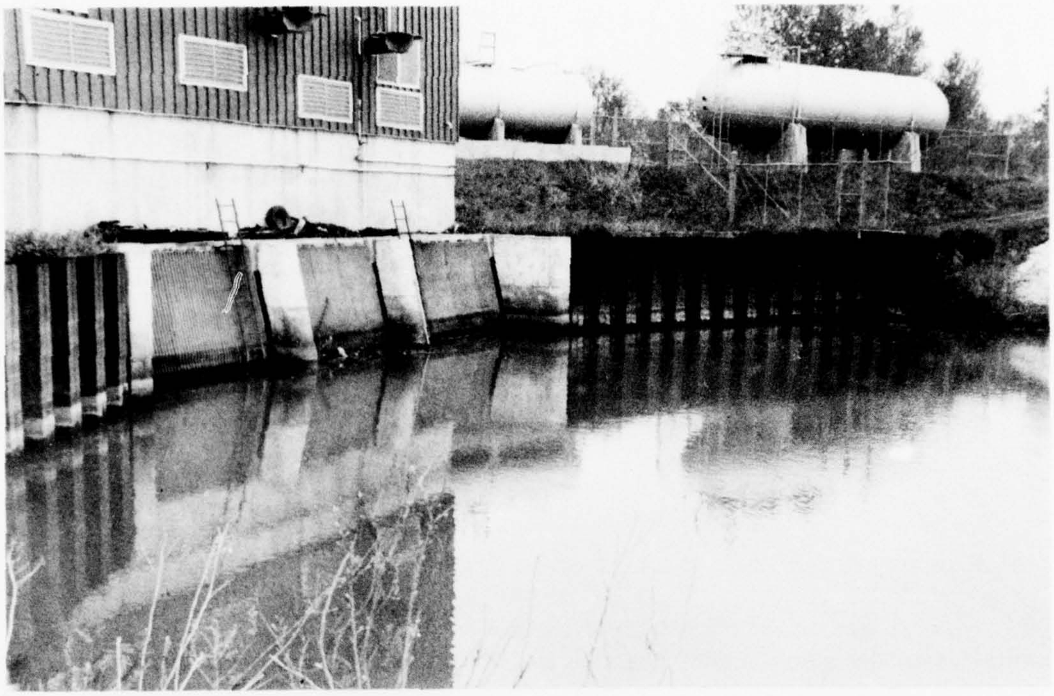

Figure 9. Entrance to sump, 45-deg wing walls, rounded pier noses, three pumps operating

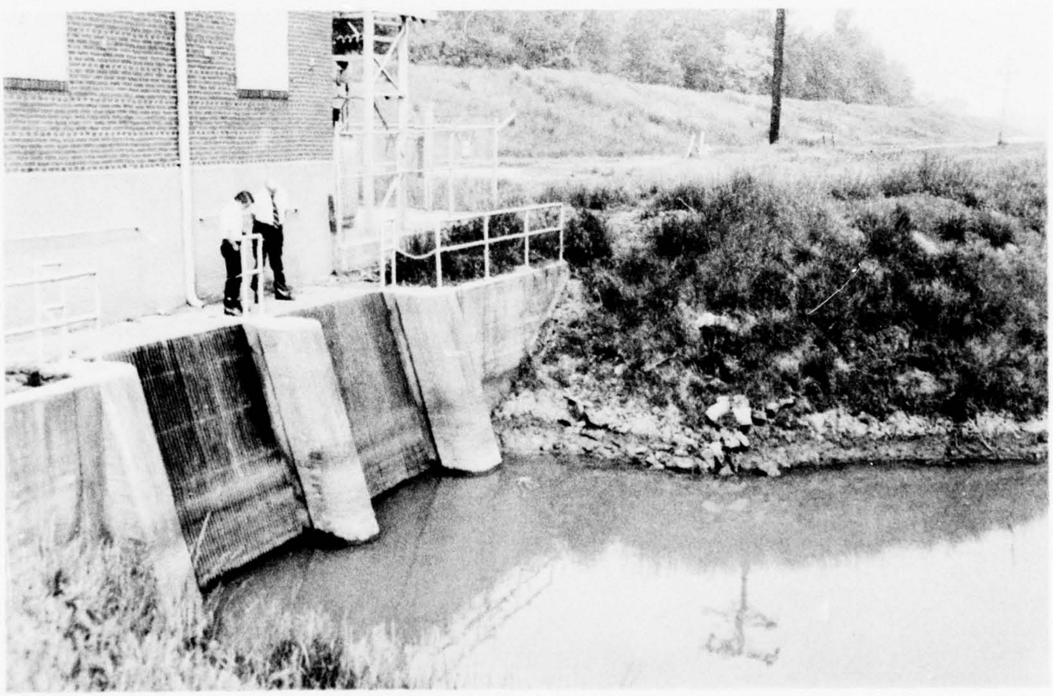

Figure 10. Entrance to sump, 90-deg wing walls, rounded pier noses, pumps not operating

Figure 11. Entrance to sump, 45-deg wing walls, rounded pier noses, pumps not operating

Figure 12. Entrance to sump, 45-deg wing walls, rounded pier noses, center pump operating

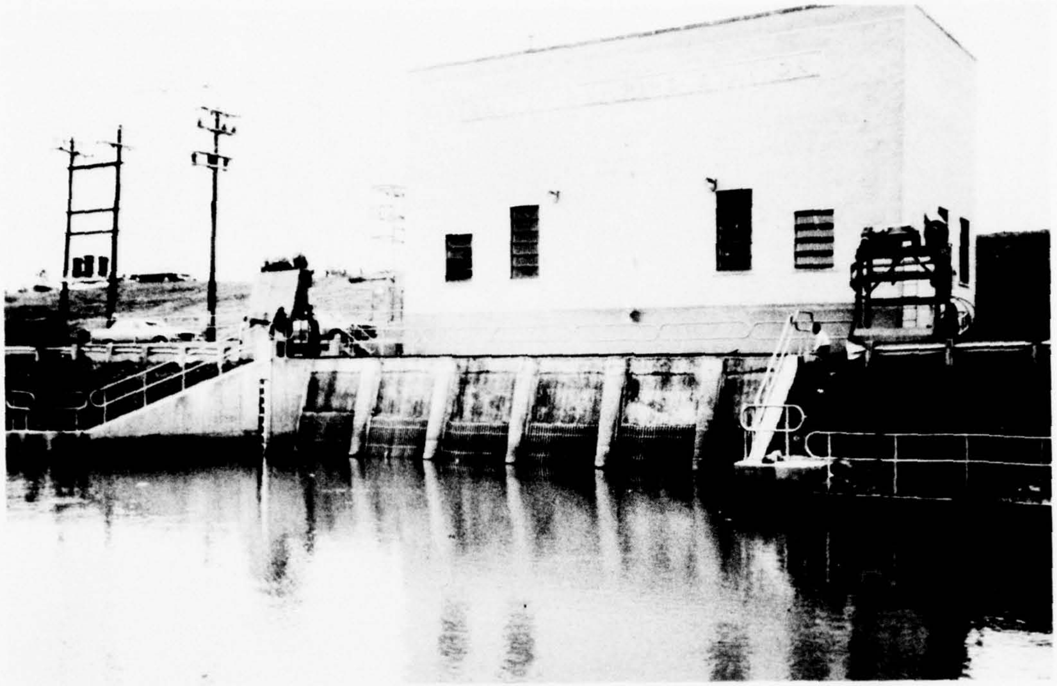

Figure 13. Entrance to sump, flared wing walls, rounded pier noses, three center pumps operating

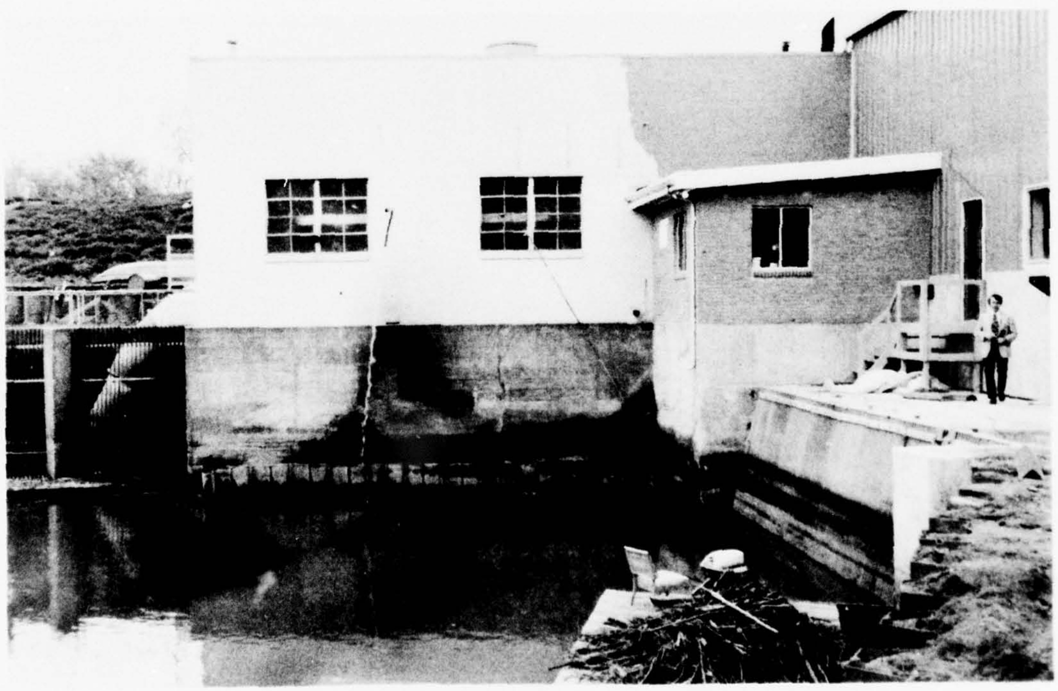

Figure 14. Entrance to sump, irregular entrance conditions, pump on left operating

Figure 15. Entrance to sump, irregular entrance conditions, pump on right operating

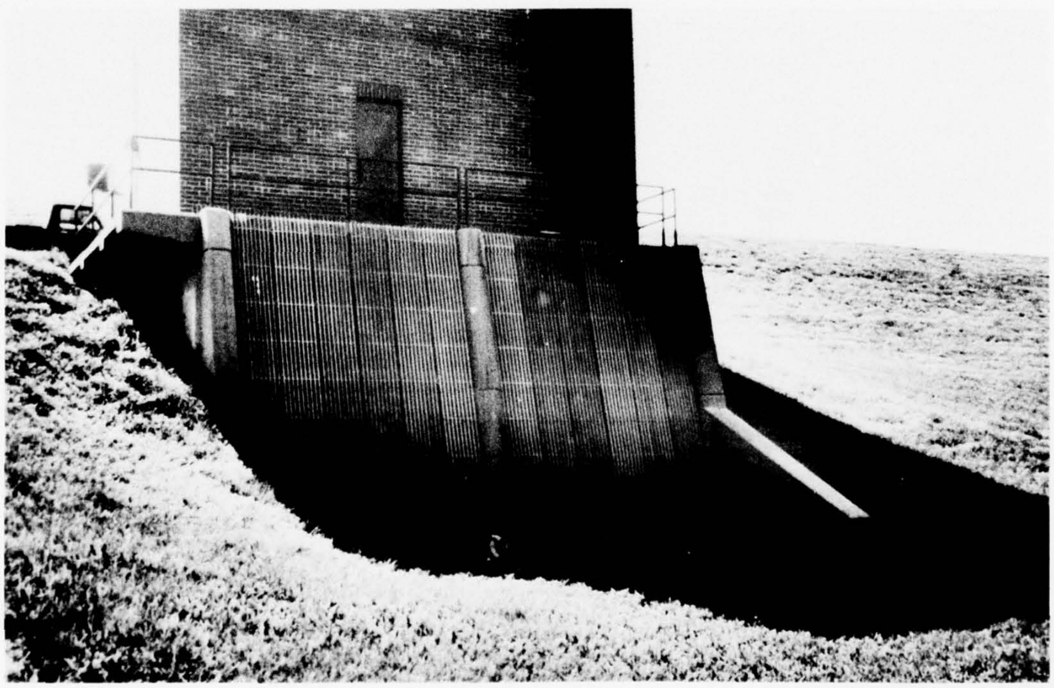

Figure 16. Entrance to sump, irregular entrance conditions, pumps not operating

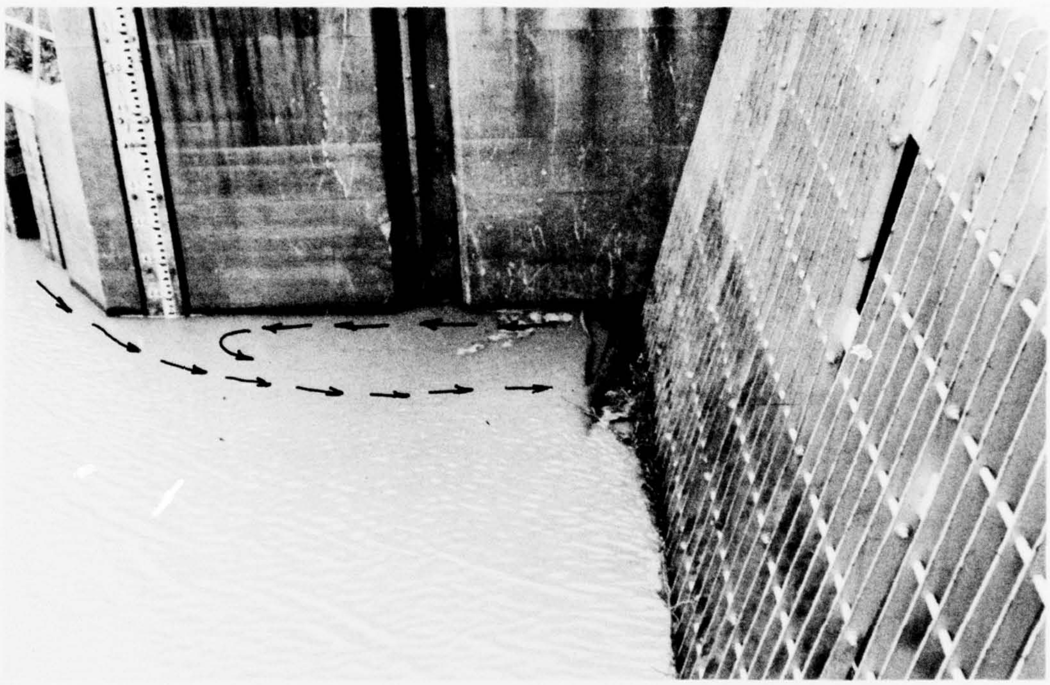

Figure 17. Entrance to sump, 45-deg wing wall, adverse circulation

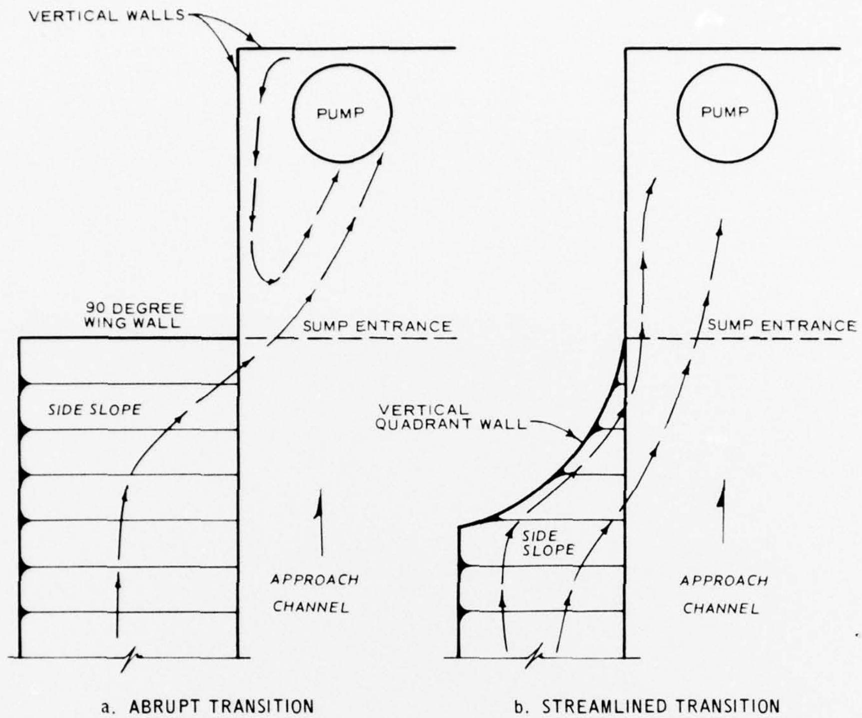

Figure 18. Types of transition from approach channel to entrance of sump

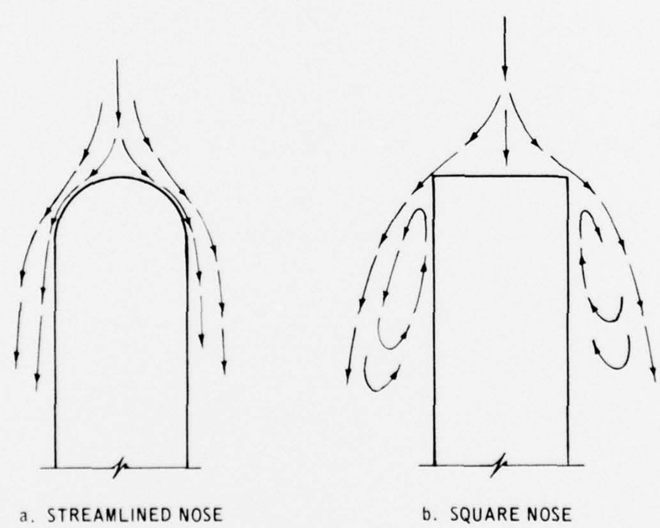

Figure 19. Comparison of flow separation of pier nose shapes

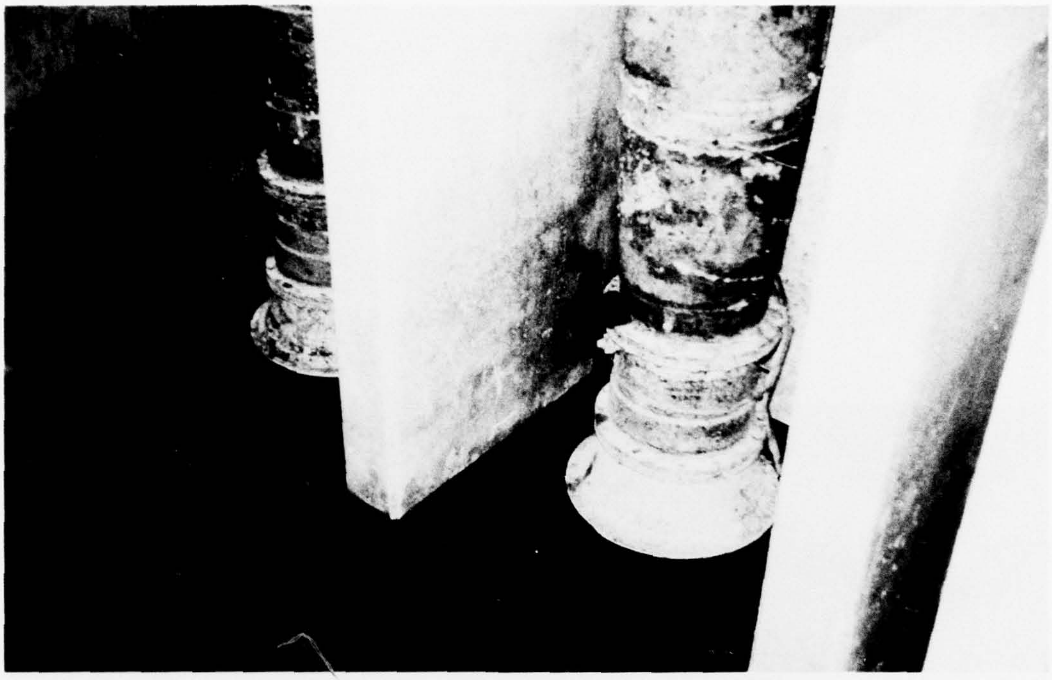

Figure 20. Divider walls to prevent mutual pump interference

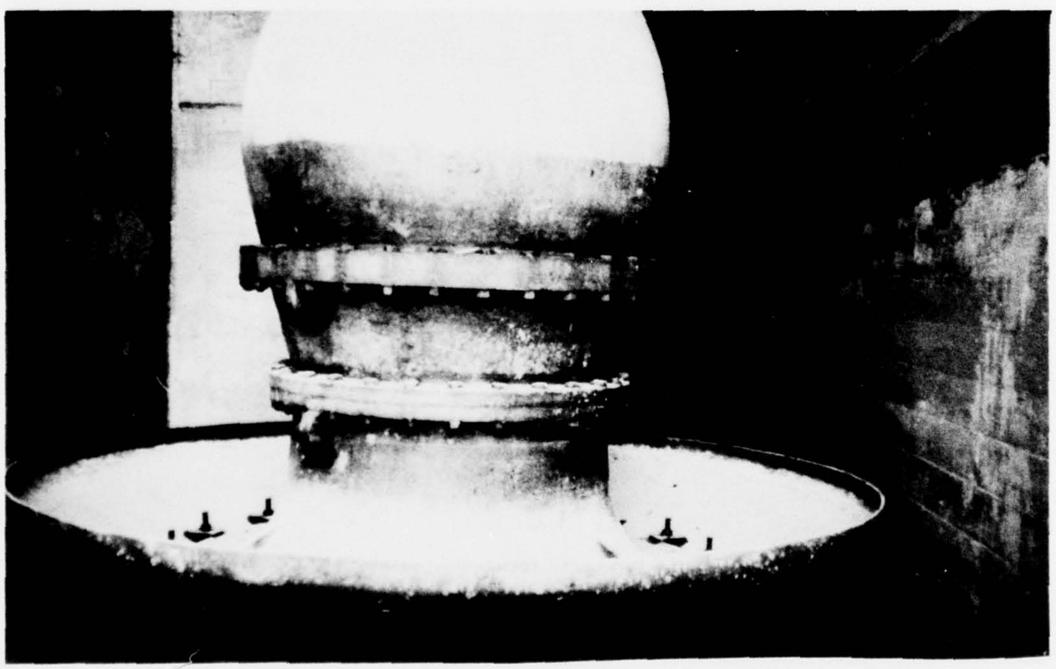

Figure 21. Umbrella to streamline flow and reduce intake velocities

Figure 22. Typical placement of umbrellas and divider walls in sump

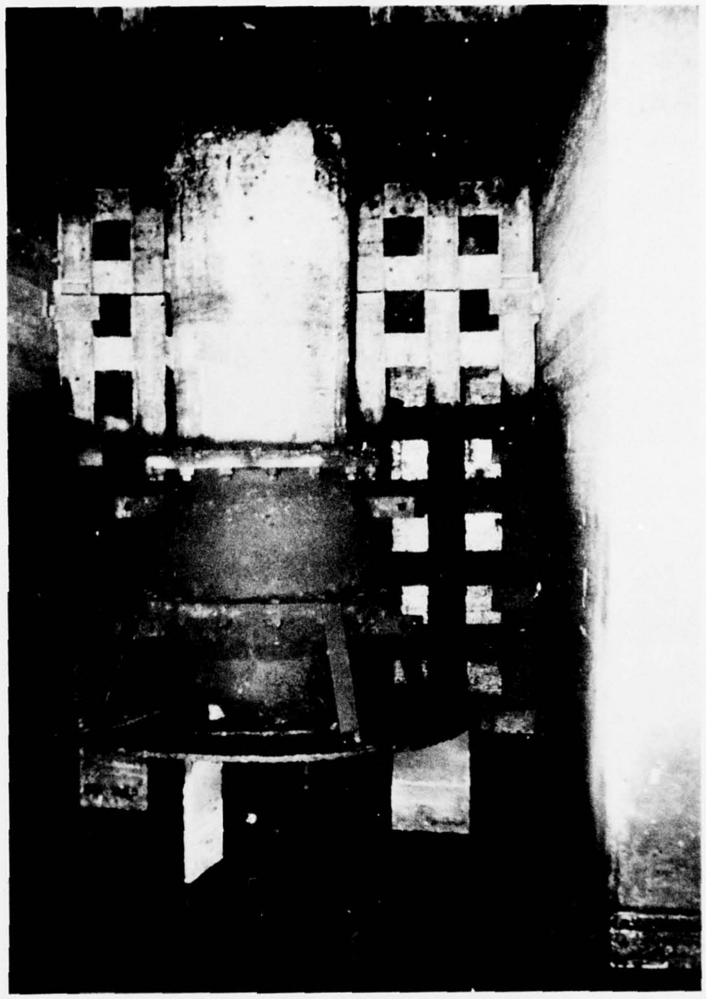

Figure 23. Vanes to straighten flow into the pump intake and a vertical grid on the back wall to attenuate vortex development

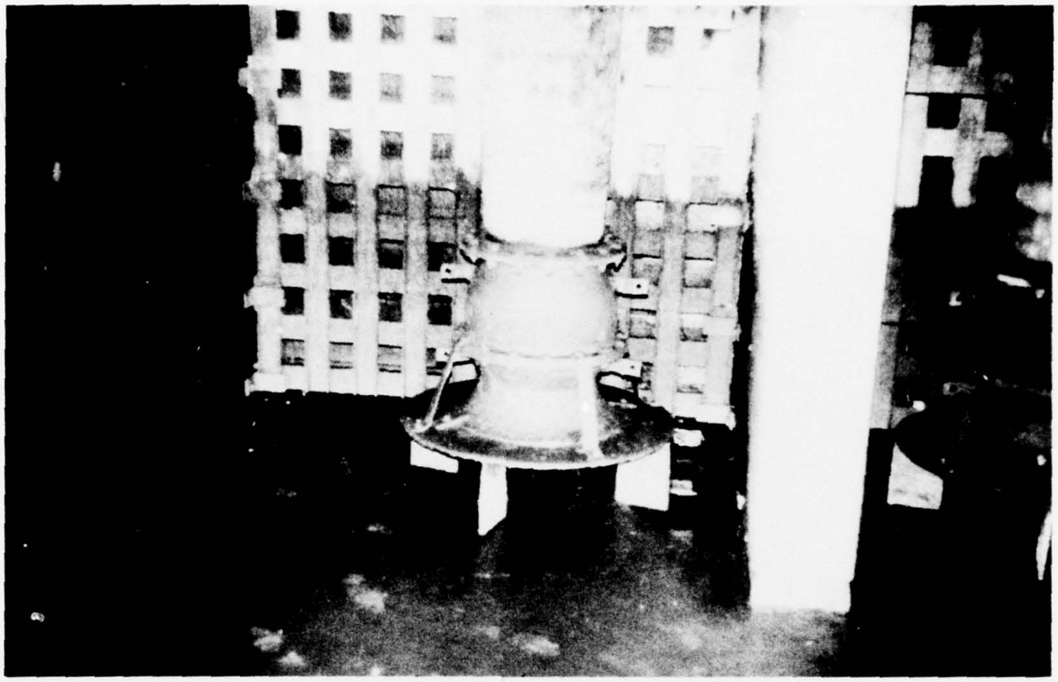

Figure 24. Divider wall, guide vanes, and vertical grid (back wall) to reduce vortex development

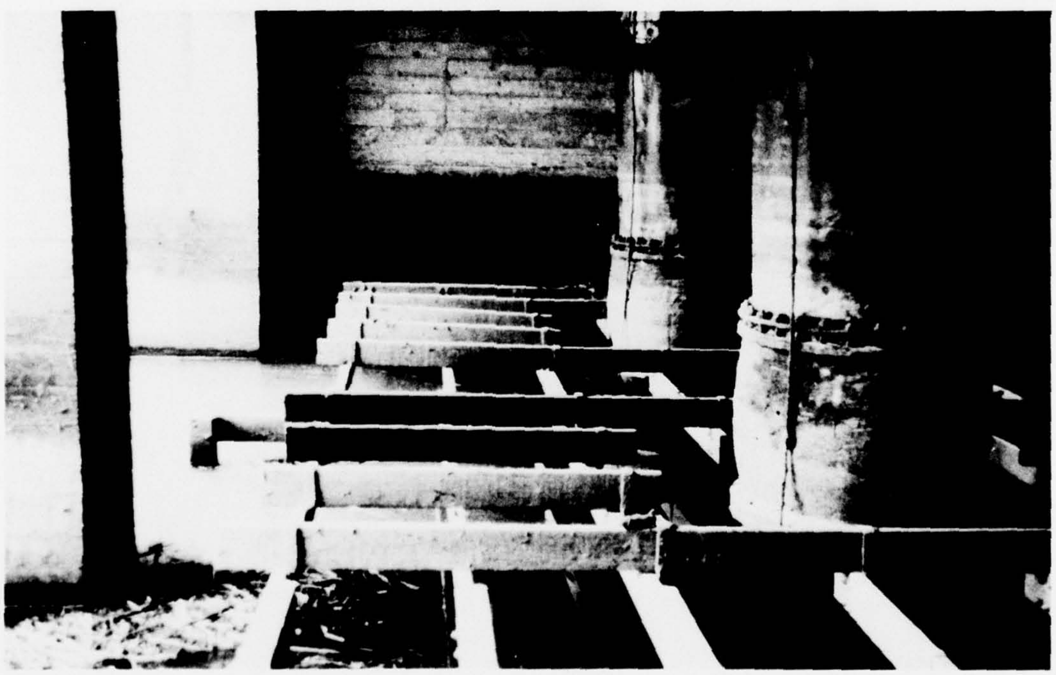

Figure 25. Floating wooden grid to minimize vortex development

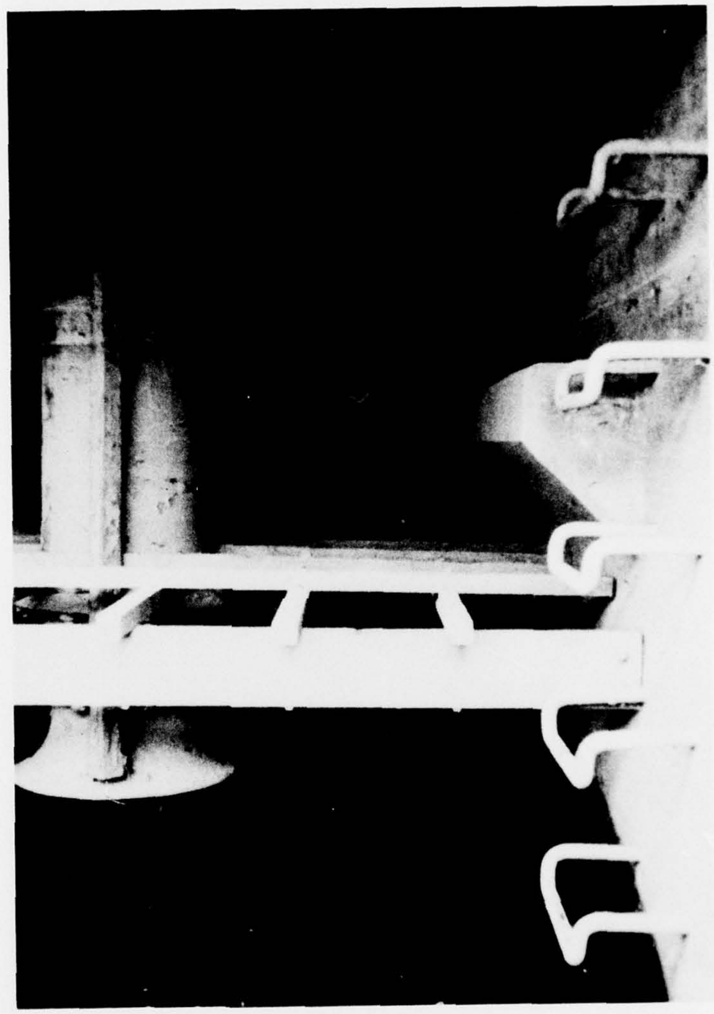

Figure 26. Fixed wooden grid to minimize vortex development

Figure 27. Surface floats to prevent air entrainment in vortexes

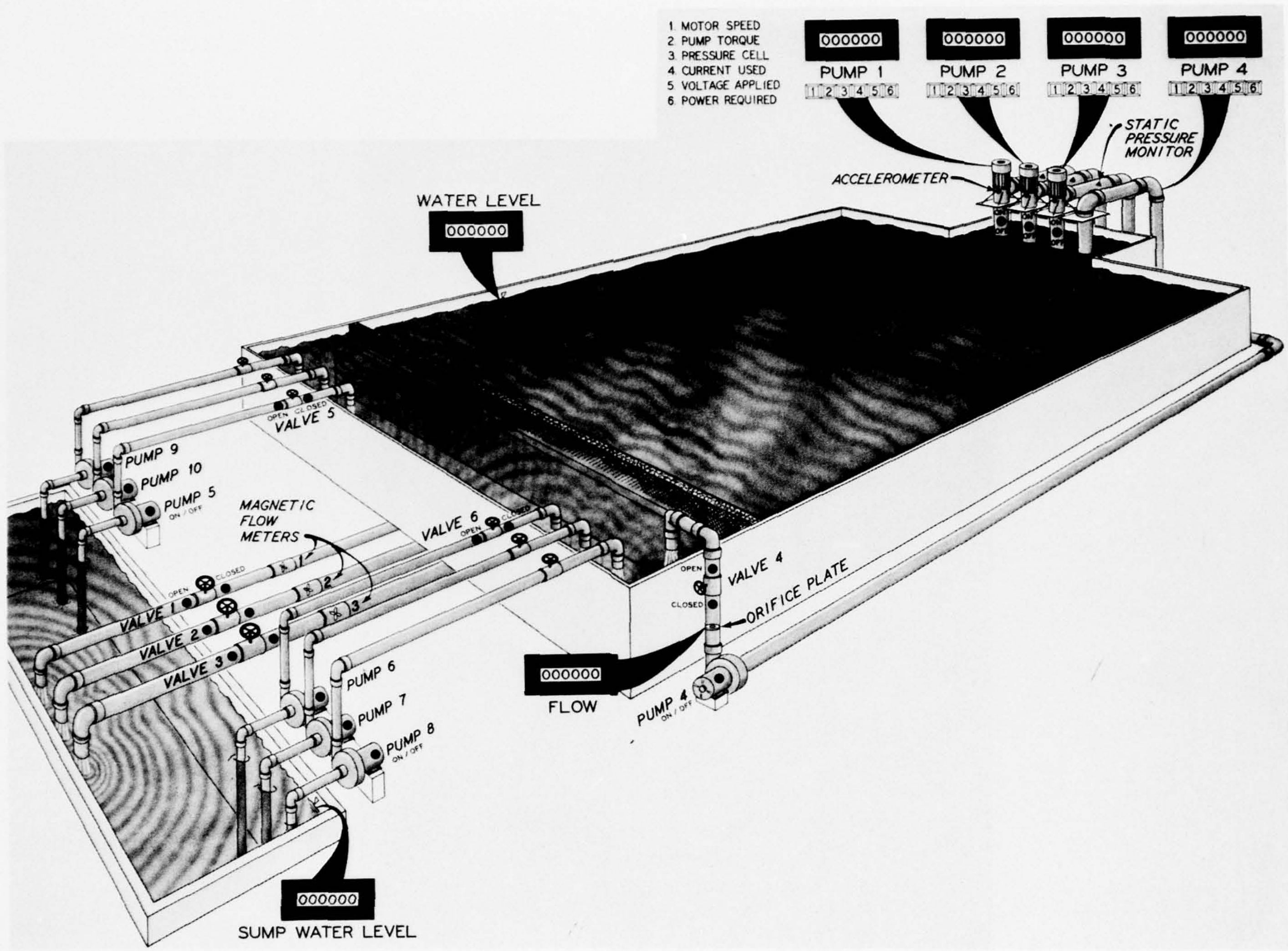

Figure 28. Pumping station research facility

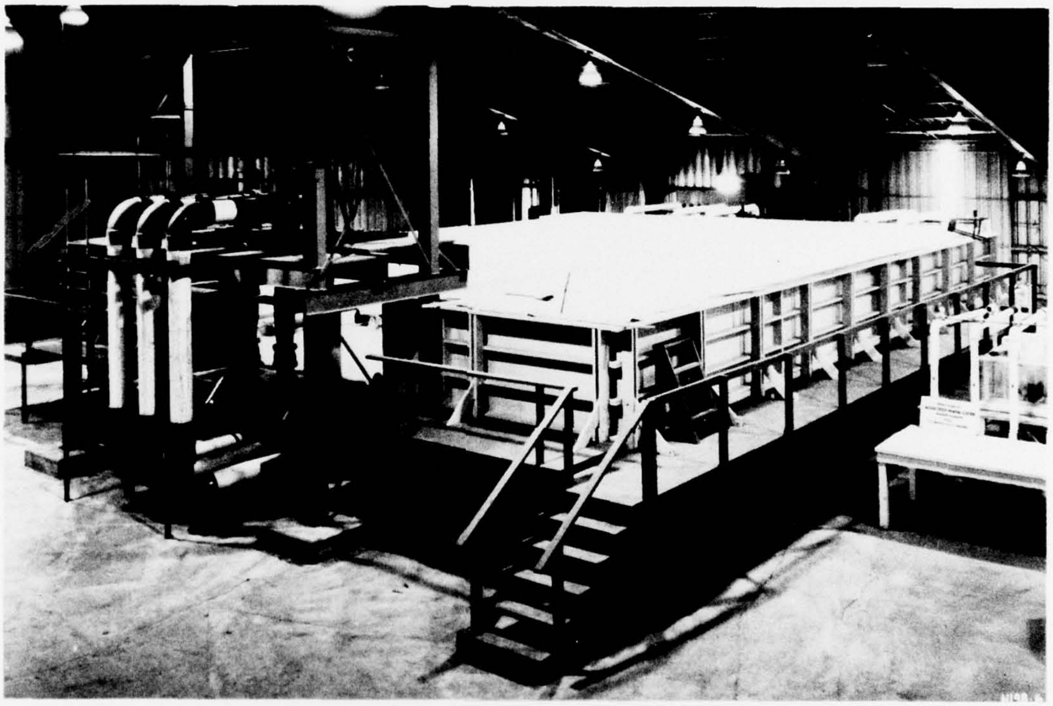

Figure 29. General view of pumping station research facility

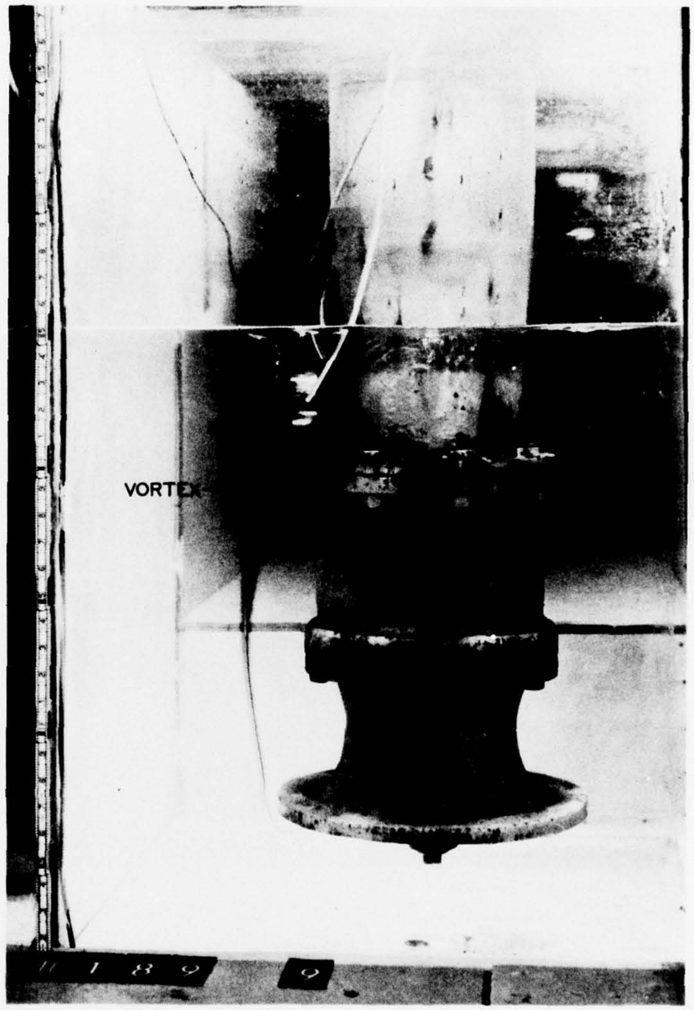

Figure 30. Surface vortex, 2000-gpm discharge,
1.3-ft submergence

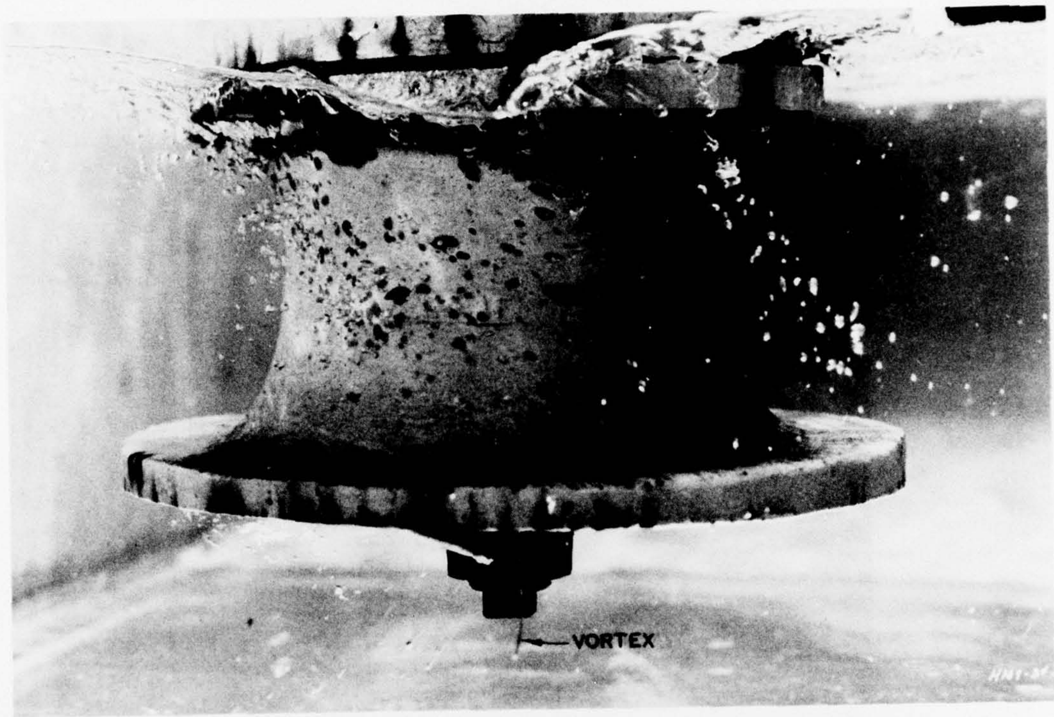

Figure 31. Submerged floor vortex, 3000-gpm discharge, 0-ft submergence

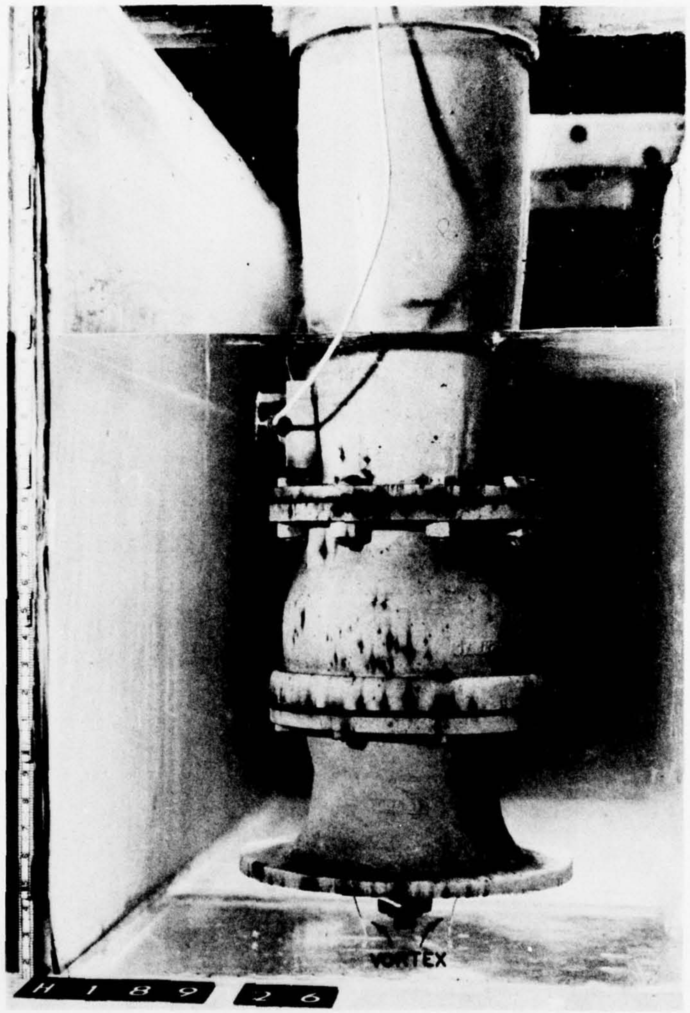

Figure 32. Submerged rear wall vortex, 3000-gpm discharge, 1.3-ft submergence

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